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APPARATUS.—*An apparatus for growing crystals under controlled conditions.* J. C. HOSTETTER, Geophysical Laboratory, Carnegie Institution of Washington.

Crystals, to be suitable for the study of the effects of pressure, must be perfectly developed and of comparatively large size. The criterion of perfect development, in this case, is not in the possession by the crystals of those rare faces that so delight the crystallographer, but in the possession of maximum strength. In general, it may be said that the causes which diminish the transparency of those crystals that are normally transparent, also decrease the strength of the crystals. Perfect transparency in a crystal results only when the rate of growth is small and constant, or nearly so, throughout the entire growing period. Nontransparency in a crystal (except that due to the inclusion of foreign solids), is usually indicative of suddenly increased growth rate with the attendant development of cleavage planes and, frequently, inclusion of mother-liquor. For growing crystals that are suitable for pressure studies there is required, therefore, apparatus in which *all* variables affecting rate of growth are under control. The degree of supersaturation in the mother liquor at any time determines the increment of growth;[1] consequently, the conditions affecting supersaturation—primarily,

[1] While this is generally true there are certain important exceptions which cannot be adequately explained at the present time. An interesting case is that of gypsum described by W. J. FAWCETT, Proc. Roy. Soc. Canada 7: 218. 1913.

temperature and evaporation—must be under definite control. Of lesser importance—but nevertheless, essential—are the direction of concentration currents, and the number of crystals which serve as nuclei for growth. When these variables are controlled it is not a difficult task to grow very perfect crystals of large size.

In this note we will confine ourselves to the growth of soluble substances from solution, and merely mention the growth of very slightly soluble substances in crystal form, which has been developed very thoroughly,[2] and the growth of crystals from melts.[3]

Neglecting the effects of hydrostatic pressure, it may be said in general that there are four methods of producing supersaturation in a saturated solution and, hence, growth of a crystal immersed therein. In a solution saturated with respect to a certain crystal phase at a definite temperature we may produce supersaturation by (1) lowering (or, in rare cases, raising), the temperature, (2) allowing the solution to evaporate, (3) dissolving in this solution held at constant temperature, extremely finely divided particles of the crystalline phase, or (4) adding another solvent in slight amount.[4] It is quite evident that a crystal-growing apparatus based on any, or a combination of all, of these principles will be satisfactory if the variables are properly controlled, but in most of the crystal-growing devices described in the literature, the governing of some of the essential conditions has been left entirely to chance. Practically, devices based on temperature change are easier to control and, probably, the most easily constructed. The apparatus finally developed and described below is based on this principle.

[2] Almost all methods for the growth of "insoluble" precipitates in crystal form are based on diffusion processes. For a discussion of the essential conditions see JOHNSTON. Journ. Amer. Chem. Soc. 36: 16. 1914.

[3] R. NACKEN has recently described apparatus for growing crystals from melts; but the crystal nucleus is supported on a wire which becomes enclosed by the crystal as growth proceeds. (Neues Jahrb., 1915, II, 145.) Such crystals are, for this reason, not suitable for pressure studies.

[4] As alcohol to an aqueous solution of a sulfate.

To the essential conditions previously discussed we must add another if the crystal-growing process is to be continuous; namely, that the supersaturated solution must be given definite circulation over the nuclei to be developed. Recently a crystal-growing apparatus with controlled circulation has been patented by Krüger and Finke.[5] In this apparatus the mother-liquor is saturated in one chamber and then passed into another chamber of lower temperature where deposition takes place on the crystal nuclei to be grown; the solution is then returned to the saturating vessel. This patent of Krüger and Finke furnished the basis for the apparatus described by Valeton[6] and the apparatus described below has been taken in part from that described by these investigators, but with numerous changes in details of construction.

Essentially the apparatus consists of 2 thermostats (S and C in figures 1 and 2), connected by tubes, with the necessary stirring and circulating devices. The thermostats are filled with saturated solution of the crystals being studied. One thermostat—the "saturator" (S)—contains the crystals, which maintain the solution saturated; the other thermostat—the "crystallizer" (C)—is held at a slightly lower temperature and it is in this cell that growth takes place. The thermostat vessels are storage battery jars, 20 by 20 by 20 cm., with 25 mm. holes drilled through the sides where necessary for the entrance of tubes. The thermoregulators[7] (shown at T and T_1) are filled with mercury, and operate, through relays, the 5-candle-power cylindrical carbon lamps (H and H_1) used as heaters. In the saturator the cooled solution stream flows over a heater

[5] German patent No. 228246, a copy of which I have been unable to secure. A brief description of their apparatus is given in W. VOIGT. Lehrbuch der Kristallphysik, p. 9, 1910.

[6] J. J. P. VALETON. Ber. Sachs. Ges. Wiss. 67: 1–59. 1915.

[7] Attention may be here called to the threaded glass parts of the thermoregulators which carry the adjustable contacts. These threaded parts are small homeopathic vials (Whitall Tatum Co.) which have been drawn down and sealed to ordinary soft tubing. I have found their use advantageous in other cases where glass-to-metal connections are necessary.

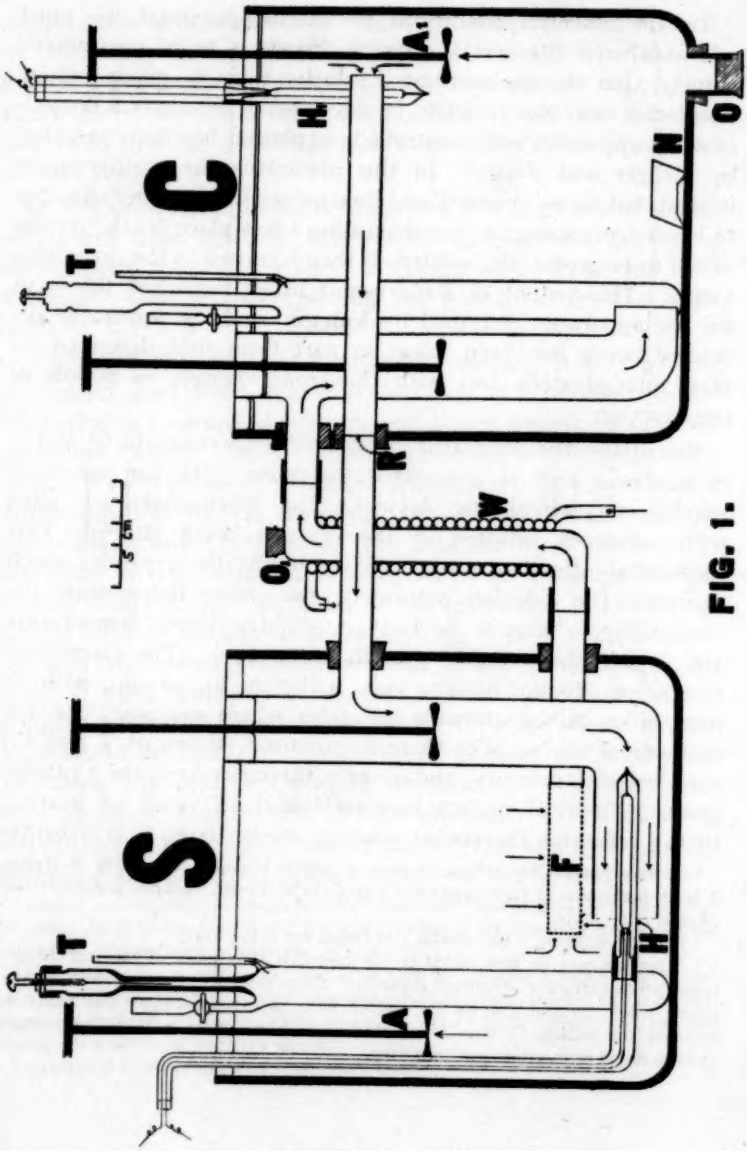
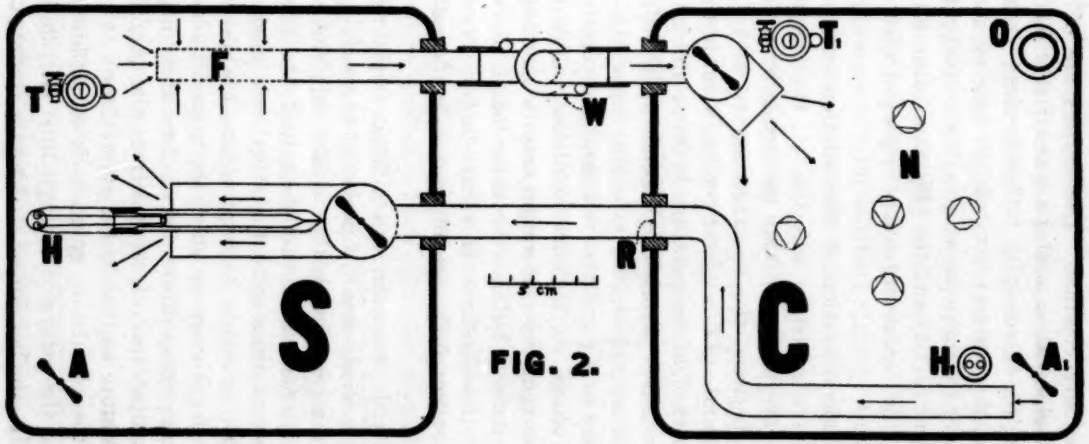


FIG. 1.



Figures 1 and 2. Section and plan of crystal-growing apparatus.

The apparatus consists essentially of two thermostats,—the Saturator (S) and the Crystallizer (C); S is maintained at a temperature slightly higher than C and is about one-third filled with crystals which keep the solution saturated. The saturated liquid is pumped from S into C where the excess material is deposited on small crystals (N), after which the solution is returned to the Saturator; the course of circulation is shown by the arrows.

(H) before striking any crystals. The stirrers are of silver. A coil of small lead pipe (W) serves as a water jacket for one of the tubes connecting the thermostats. The openings (O and O_1) permit the removal of volunteer crystals, in case of accident, without disconnecting the entire apparatus; for a similar reason the return tube is cut at (R) and the platinum gauze filter (F) may be detached. The entire apparatus is packed with felt in a large, wooden box.

The degree of supersaturation of the solution entering the crystallizer may be controlled by adjusting (1) the temperature difference between the saturator and the crystallizer, (2) the rate of circulation between the two thermostats, and (3) the temperature and the rate of flow of the cooling water in the coils at (W). The difference in temperature between the saturator and the crystallizer that is permissible depends upon the change of solubility with temperature, and especially upon the extent to which the solution of a particular salt can be supersaturated. In the case of the alums, for instance, solutions containing salt equivalent to 15 per cent supersaturation may be handled without causing precipitation, but on the other hand the change of solubility with temperature is fairly large. Practically, therefore, a temperature difference of 0.3° to 0.5° was found to give good growth.

With other materials, however, this difference might be too large and if so there would result a period of excessive growth, or a shower of volunteer crystals that would ruin the crystals being developed. No measurement of the actual rate of transfer of solution from one thermostat to the other was made. The rate of stirring must obviously be kept constant while crystals are being grown. If the room in which the apparatus is placed is subjected to large temperature fluctuations it is necessary to maintain the temperature of the water in the cooling coils at the same temperature as that of the crystallizer.

The course of the circulating solution is as follows: The solution comes into the saturator through tube (R), flows over the heating lamp (H), the hot stream striking the feeding crystals

and becoming saturated. Before the solution returns to the crystallizer it must pass down between more crystals into the platinum gauze filter at (F); thence to the crystallizer. *En route* it is cooled slightly in the water-jacketed tube before entering the crystallizer. The supersaturated current now passes over the nuclei at (N) and excess material deposits thereon. The cooled solution returns through (R) to the saturator. The currents caused by the auxiliary stirring (A and A_1) in the thermostats are such as to assist the main circulation between the two thermostats.

Instead of depending upon chance for the formation of nuclei it is far better to introduce small well-formed crystals which have been developed elsewhere. If a warm saturated solution is allowed to cool overnight there will usually be some small crystals that are suitable as nuclei. Where these crystals have been in contact with the bottom of the vessel there is under each one a small terraced cavity. This has been brought about partly by the fact that mother-liquor did not have access to the bottom surface during growth. While growing in this manner the original nucleus may be lifted several millimeters. When these crystals are placed in the crystallizer they should be oriented with the cavity on top. New growth will soon build up the top to a plane surface. Each day the crystal should be turned over so as to avoid the development of deep hollows underneath. The crystals should likewise rest on plane glass and not on the irregular bottom of the battery jar. Before introducing crystals into the crystallizer it is advisable to dip them into a saturated solution (as in the saturator) and wash off loose particles.

It has been mentioned that the rate of growth is also influenced by the number of nuclei. With a temperature difference of 0.3–0.5° and 5 nuclei present the rate of growth for potash alum was about 1.0 mg. per hour per sq. cm. of crystal surface exposed to the solution.

The surface of the solution in the saturator was uncovered and evaporation allowed to take place—thus helping in the

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maintenance of saturation. In the crystallizer, however, the only supersaturation desired is that under control and consequently evaporation was prevented by a layer of kerosene floating on the solution. Crystals introduced into the crystallizer were lowered beneath the oil in a bottle.

It is of great advantage to have large crystals or aggregates of crystals for use in the saturator to serve as "raw material" from which to grow well developed crystals. In the case of the alums, for instance, large-sized material is commercially available, and such is the case with numerous other salts. Where material can not be secured in large particles the finely-divided salt must be used and as this can not be piled up in the saturator like large-sized material, recourse is had to the use of small bags suspended in the solution and refilled from time to time with the fine crystalline material. Under the influence of the oscillating temperature obtaining in the solution in the saturator such finely divided material soon coalesces into aggregates which are entirely suitable for this purpose.

If the presence of fine thread or of wire is not objectionable in the final crystal the nucleus may be suspended in the solution by such means. This avoids the necessity of turning the crystal each day and also gives a more symmetrical crystal. Crystals grown around such suspensions are usable for a great variety of purposes but as pointed out previously such crystals are not suitable for pressure investigations.

Even though the crystals grown under thoroughly controlled conditions appear beautifully clear and perfect to the unaided eye, microscopic examination[8] frequently reveals the presence of minute inclusions, the causes of which require further study. Also, it may be mentioned here that "isotropic" crystals grown under these conditions often show zones of local strain when examined in polarized light.[9]

An observation may be recorded here regarding the development of faces on alum crystals. As normally grown such crystals

[8] Very kindly made by my colleague Dr. H. E. MERWIN.

[9] WRIGHT, F. E., and HOSTETTER, J. C. Journ. Wash. Acad. Sci. 7: 415. 1917.

form flattened octahedra, diagrams of which are shown in position in the sketches of the crystallizer. Ordinarily such crystals are nearly free from any of the related faces such as the cube and the rhombic dodecahedron; the cube face may be observed but it is always small and the rhombic dodecahedral face is even less developed. Such is the case when the crystals are grown continuously without periods of solution intervening. If, for any reason, the growth of the crystal is stopped and solution of the crystal takes place the edges of the crystal are rounded in the initial stages of dissolution: when conditions are changed so that growth recommences the rounded portion of the crystal flattens during growth and in so doing a rhombic dodecahedral face is developed. During the future growth of the crystal this new face is very prominent and in none of the cases observed here has it ever filled out to form the sharp edge of the original octahedron. A similar development of the rhombic dodecahedral face can be induced if the edge of the octahedron is removed by other means and the crystal then allowed to grow. The "repair" of crystals during growth is thus seen to follow along the lines of least resistance.

It should be emphasized here that the mere fact that all essential conditions are under control in the crystal-growing apparatus described above, is not, in itself, a guarantee that any salt can be made to form large crystals under the conditions obtaining therein. Some salts may be readily enough crystallized in large well-formed crystals—other salts under the same conditions will yield a multitude of small crystals rather than a few large ones. Potassium alum and sodium chlorate were grown very successfully in this apparatus but experiments with ammonium chloride yielded only a mass of fine, fernlike crystals instead of growth on certain crystals which had been introduced as nuclei. In this case the effect was not caused by incorrect adjustment of conditions for these fine crystals appeared and increased in size in the crystallizer, thus showing that conditions were optimum. On several occasions all crystals except one were carefully removed from the crystallizing chamber

and circulation of liquid continued, but here again, instead of deposition taking place on the remaining crystal, other nuclei were formed developing later into the usual fernlike growths. These experiments were repeated under a sufficient variety of controlled conditions to show that the phenomenon was connected with certain relations at present beyond our control.

The literature is filled with observations on the effect of foreign material on crystal habit but experience gathered in the course of these investigations has shown that, in general, such effects have been largely overestimated, at any rate in certain classes of salts. Furthermore, it will be shown in future publications that there is nothing mysterious about the action of addition products in many cases, but that a simple explanation based on well-known physico-chemical laws will suffice.

The crystals grown in this apparatus have been used in the study of certain problems connected with the linear force of growing crystals,[10] and also the effects of nonuniform pressure on solubility.[11] The publication of other results, delayed by the war activities of this Laboratory, will be made as opportunity permits.

CRYSTALLOGRAPHY.—*X-ray analysis and the assignment of crystals to symmetry classes.* ALFRED E. H. TUTTON, Past President of the Mineralogical Society of London. (Communicated by R. B. Sosman.)

A memoir on the above subject is contributed by Edgar T. Wherry to a recent issue of this JOURNAL[1] which calls especially for some notice, inasmuch as it is largely based on certain misconceptions regarding fundamental crystallographic facts, of a type which is becoming increasingly common among the growing number of workers and writers on this new and highly inviting subject of X-rays and crystals. The memoir in question assumes that evidence has been accumulating that the crystals of

[10] BECKER, G. F., and DAY, A. L. Journ. Geol. **24**: 313–333. 1916.

[11] HOSTETTER, J. C. Journ. Wash. Acad. Sci. **7**: 79. 1917. WRIGHT, F. E., and HOSTETTER, J. C. Op. cit. **7**: 405. 1917.

[1] This JOURNAL **8**: 480. 1918. Compare also Dr. WHERRY'S reply, p. 99.

certain substances—notably the diamond, sylvine (potassium chloride), pyrites and its analogues hauerite and cobaltite, the nitrates of barium, strontium, and lead, and the rutile group of minerals—are in a sense intermediate in structure between two crystal classes, possessing some of the attributes of each. It is advocated that the difficulty be overcome in each of such cases by assigning the substance to both classes. It is further assumed that they are usually cases of weak hemihedrism.

The diamond, although formerly classed as hexakis-tetrahedrally hemihedral (class 31), has for some time now, largely owing to the very definite proof of the absence of electric polarity by Van der Veen, been considered as holohedral, that is, as belonging to the class 32 of full cubic symmetry. This view has now been shown to be correct by W. H. and W. L. Bragg, as the result of their X-ray structural analysis. The memoir of Dr. Wherry, however, regards the Bragg result as indecisive, and as indicating holohedrism as a whole, but a tetrahedral structure-unit symmetry. Etch-figures are considered to bring out partial symmetries when equilibrium is delayed, and in the case of diamond they are at first hemihedral, but given longer time become eventually holohedral. It is concluded in the memoir, therefore, that while the system of diamond is cubic, and the space-lattice structure is holohedral, the structure-unit is tetrahedral.

In the case of sylvine, also found holohedral by X-ray analysis, the etch-figures indicate gyrohedral (class 29) symmetry, which it is assumed is due to the difference in atomic volume of potassium and chlorine; whereas in the case of rock-salt, which is undoubtedly holohedral (of class 32), although class 29 etch figures are also produced at first, they are subsequently further developed into class 32 figures and this is supposed to be due to the near equality of the atomic volumes of sodium and chlorine. The memoir finally concludes that this family of halides belongs to the cubic system, with a holohedral space-lattice and a gyrohedral structure-unit.

With regard to the pyrites family of minerals, it is considered that the Bragg results indicate that the space-lattice and crystal molecules of pyrites, FeS_2 and hauerite, MnS_2, in which the two negative atoms are alike, possess pyritohedral (pentagonal dodecahedral) symmetry, and those of cobaltite, CoAsS, in which the two negative atoms are different, "tetartohedral" symmetry. As some specimens of pyrites exhibit tetartohedral traits it is further assumed that the structure of pyrites is Fe = S = S, the two sulphur atoms being of different valency; tetradic and dyadic. The whole group is described as belonging to the cubic system, with a "pyritohedral space-lattice" (*sic*, particularly definitely stated in the table given), and a tetartohedral structure-unit.

Barium nitrate and its strontium and lead analogues are similarly assumed, from the X-ray results of Nishikawa and Hudinuki, to have "pyritohedral space-lattices," with a tetartohedral structure-unit in each case.

Rutile, TiO_2, is assumed to be of holohedral habit, but to exhibit occasionally trapezoidal hemihedrism. The somewhat contradictory X-ray results of Vegard and of Williams are discussed, and the views of Williams adopted as more reasonable. The conclusion is that the system is tetragonal, the space-lattice holohedral, and the structure-unit trapezoidal.

The final conclusion in the memoir is that both the symmetry of the space-lattice as a whole, and that of the crystal molecules or unit cells of the space-lattice, may find expression in significant physical features, and that both should be taken into account in the assignment of crystals to symmetry classes, even although it may be necessary at times to state two different classes for the same crystal.

With the first portion of this conclusion all can agree, provided (as is not stipulated in the memoir) that it be kept clear as a fundamental fact, that it is the space-lattice that determines the crystal-system and the obedience to the law of rational indices, while it is the structural detail (represented only by a point in the space-lattice) that determines which particular

one of the 32 classes of possible crystal-symmetry is developed. But with respect to the last sentence of the conclusion—that a crystal can be allocated to two different classes—it is absolutely, fundamentally, wrong and entirely unacceptable. There is no more accurate science than modern crystallography. The old method of regarding crystal-classes as holohedral, hemihedral (half the faces suppressed), and tetartohedral (three-fourths of the possible faces suppressed) is gone forever, and crystal classification is now at length scientifically and very definitely based on the possession of fixed elements (planes and axes) of symmetry, every one of the 32 possible classes of crystals having its own absolutely unique elements of symmetry. A structure either possesses the elements of symmetry of a particular class or it does not; there is no halfway house.

The greatest misconception in the memoir, however, and one which probably gave rise to that just alluded to, is that a space-lattice can be anything but holohedral (*e. g.*, the frequent reference in the memoir to the pyritohedron as a space-lattice). Now there are only fourteen space-lattices, those which Bravais verified and immortalized after their original discovery by Frankenheim, and all are essentially and necessarily holohedral (retaining this term as a convenient one to express full systematic symmetry). They are too simple to be anything else. The three belonging to the cubic system (for all the seven systems are represented among the fourteen) are those having for their elementary cells the cube (No. 1), the centered cube (No. 2) which is a cube with a point at the center, and the face-centered cube (No. 3), a cube with a point in the center of each face. If each point of these lattices be imagined to represent a polyhedron of such a nature that when an unlimited number are packed together in contact, space is completely filled, the No. 1 polyhedron would be a cube, which is obviously a triparallelohedron; that of No. 2 space-lattice would be a cubo-octahedron, an octahedron so far modified by faces of the cube that each octahedral face has the shape of a regular hexagon, the solid being a heptaparallelohedron; and that of No. 3 would be a

dodecahedron, a hexaparallelohedron. The point-systems corresponding to the crystal-classes of lower than the full systematic symmetry are not space-lattices at all, but Sohncke regular point-systems, including in many cases those involving enantiomorphism added by Schönflies, Fedorov, and Barlow, and later also accepted by Sohncke. The pyritohedron, the "hemihedral" pentagonal dodecahedron, referred to in the memoir and its accompanying table as a space-lattice, is not a space-lattice, but a Sohncke regular point-system; indeed Sohncke allocates three of his point-systems, Nos. 54, 55, and 56 to the pyrites class 30. As the space-lattice is always holohedral, the suggestion made in the memoir, if carried out, would result in every substance belonging to a class other (lower) than the holohedral class of the system to which it conforms being relegated not only to that subsidiary ("hemihedral" or "tetartohedral") class in question, but also to the holohedral class of the system, that is, to two different classes of the same system, possessing quite different elements of symmetry, which is absurd. For all structures, even "tetartohedral" ones, have a fundamental space-lattice, about the nodes of which their detailed atomic structure may be considered as grouped. Indeed, the point-systems may quite legitimately be, and often are, considered as composed of interpenetrating space-lattices.

It cannot, therefore, be made too clear that the space-lattice only determines the crystal system and not the class. It expresses the grosser crystal structure, that of the molecules or polymolecular groups, each point or node of the lattice representing a single molecule or the small group of two, three, four, etc., molecules necessary to the complete crystal structure. It is the whole structure, including the detailed arrangement of the atoms in the molecule or group, which determines the class. Pyrites most certainly belongs to the dyakis dodecahedral class 30, of which the pentagonal dodecahedron is a prominent form, the third of the five cubic classes; but its space-lattice is No. 3, the centered-face cube, just as in the case of the alkali chlorides. Hauerite is similar, but there is some evidence from the Braggs'

results that cobaltite may belong to the tetrahedral pentagonal dodecahedral class 28, like barium nitrate. The Braggs have shown that the alkali chlorides are most probably holohedral. The rutile group requires much more research, there being no satisfaction in building conclusions on contradictory data.

The present moment is a dangerous one in the history of the use of X-rays in unravelling crystal structure. No more speculations built on incorrect crystallography are desirable. What is needed is solid, well and carefully carried out, prolonged and thoroughly tested experimental work, and a complete revision of the principles on which results are based, with the view of rendering them both more fully trustworthy and of definite application. Two fundamental problems are especially urgently requiring solution before much further progress can be made, namely, the falling away of reflection intensity with increase of order of spectrum, and the quantitative relationship between reflection-intensity and atomic number or atomic weight (mass). While we cannot hope to get much more information from the Laue radiograms than at present, the Bragg spectrometric method is full of promise, and when these root-problems are satisfactorily settled much more progress may be expected to be made with the finer details of the structure of the more important crystalline substances.

YELVERTON, S. DEVON, ENGLAND.
NOVEMBER 18, 1918.

CRYSTALLOGRAPHY.—*Reply to Dr. Tutton's discussion of the assignment of crystals to symmetry classes.* EDGAR T. WHERRY, Bureau of Chemistry.

In the course of his scientific study of natural phenomena, man is continually devising pigeon-holes into which to distribute given series of facts. Nature, however, often refuses to be pigeon-holed, and persists in bringing to the attention of all who will stop, look, and listen numerous facts which do not accord with the classification in vogue at a particular time. New classifications must therefore be continually worked out

as science advances; and this may be just as true in crystallography as in any other field. In the paper under discussion[1] the writer endeavored to point out an instance where changes in view-point appear to be needed, and is glad to take up Dr. Tutton's criticism (preceding article) and to show that the difference between us consists chiefly in our willingness to admit the above proposition. Dr. Tutton's summary of the paper in question is reasonably adequate; but whether that paper is based on "misconceptions regarding fundamental facts" must be decided by the reader of the present discussion.

The magnificent research on diamond by Fersmann and Goldschmidt[2] has surely established for all time the fact that tetrahedral (Class 31) features are often shown by both the habit and the etch figures of this mineral. The proof of the absence of electric polarity by Van der Veen, which no attempt has been made to discredit, can not alter that fact. What is needed is an explanation of the apparent discrepancy, and that is what the writer endeavored to supply. The structure of the mineral having been established to the satisfaction of all concerned by the Braggs, the writer saw therein a way to account for the difficulty, for the structure as a whole, with which the electric polarity is presumably connected, is admittedly holohedral (Class 32) while the symmetry of the unit cells is tetrahedral (Class 31), which is reflected in the habit and etch-figures. In other words, the writer accepts the correctness of the work of all the authors, whereas those by whom diamond "has for some time now ... been considered as holohedral" must ignore or discredit the work of Fersmann and Goldschmidt, as well as overlook the significance of the Bragg demonstration that the symmetry of the unit cell of diamond is less than that of the structure as a whole. The last sentence of the writer's conclusion, which Dr. Tutton considers "absolutely, fundamentally

[1] This JOURNAL, 8: 480. 1918.

[2] Through the writer's failure to correct proof of his paper the title of the work by these authors was given as "Diament" instead of "Diamant." Also, the heading of the last double column of the table should, of course, read "atomic."

wrong and entirely unacceptable" is, as the writer endeavored to show, a direct corollary to the Braggs' work. And since Dr. Tutton elsewhere in his discussion accepts the results of the Braggs, it seems evident that he does not appreciate the writer's viewpoint at all.

The writer made no attempt to revive the "old method of regarding crystal classes as holohedral, hemihedral, and tetartohedral," but merely used such terms, following Dana, as convenient, brief designations of certain symmetry classes. None of his conclusions would be altered were the classes to be referred to by numbers or by any other method. Nor has he denied that "every one of the 32 possible classes has its own absolutely unique elements of symmetry" or that "a structure [as a whole] either possesses the elements of symmetry of a particular class or it does not."

It certainly seems inconsistent in Dr. Tutton to assert that "there are only fourteen space-lattices," in the same paper in which he accepts the correctness of the Braggs' work on diamond. For the structure they assign to that mineral, though not included among Bravais's fourteen, is, *according to the criterion used by Dr. Tutton in his discussion*, a space-lattice. Each point of this structure may be "imagined to represent a polyhedron of such a nature that when an unlimited number are packed together in contact, space is completely filled." In this case the polyhedron is a regular tetrahedron, so far modified by faces of the rhombic dodecahedron that each tetrahedral face has the shape of a regular hexagon.[3] X-ray studies have shown, moreover, similar lattices to exist, as for instance a trigonal one in bismuth. How many others may be discovered by subsequent research the writer would not venture to predict, but he certainly would not claim that our present knowledge is complete and final in this (or any other) respect.

As far as pyrite is concerned, the underlying structure is admittedly not a simple space-lattice, but compound, or com-

[3] Compare ADAMS. *Note on the fundamental polyhedron of the diamond lattice.* This JOURNAL 8: 240. 1918.

posed of two interpenetrating simple ones. The disagreement over this point, therefore, is merely a matter of definition of terms, Dr. Tutton preferring to use "interpenetrating point-system" for what the writer would call a "compound space-lattice." Substitution of the one term for the other would not alter the conclusions reached in the original paper to the slightest degree. It should be noted, further, that the view that molecules rather than atoms occupy the points or nodes of space-lattices has been rather definitely disproved by the very X-ray study of crystals which started the present discussion.

To summarize: in the paper under discussion, the writer assembled the data for a number of crystals, in the assignment of which to symmetry classes one method of study gives results which conflict with those of other methods of study. He presented an interpretation of the relations which appeared to him capable of reconciling these discordant results, involving the new conception that crystals may belong to one symmetry class with respect to some properties and to another class with respect to other properties. Dr. Tutton apparently feels that the present views of crystallography are adequate to explain all past (and future) crystallographic observations. Rather than recognize that diamond, pyrite, etc., belong simultaneously to two different classes, depending on what property is considered, he prefers to ignore observations which do not accord with the one of these symmetry classes which for one reason or another he wishes to accept for each substance. In diamond, he overlooks the Class 31 habit and etch-figures, in pyrite the Class 28 habit and electrical phenomena, and so on. The writer does not believe that ignoring results which do not suit a preconceived theory is the proper scientific spirit, and prefers to modify or revise current ideas when necessary to explain undeniable observational facts, even though this may lead to his being accused of putting forward "speculations built on incorrect crystallography."

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. The abstracts should conform in length and general style to those appearing in this issue.

PHYSICS.—*The conditions of calorimetric precision.* WALTER P. WHITE. Journ. Amer. Chem. Soc. **40**: 1872–1887. December, 1918.

In a calibrated calorimeter practically all the errors come in temperature measurement, and the most, though often not the greatest of these come in the "cooling correction," that is, the determination of the effect of the thermal leakage between calorimeter and environment. This thermal leakage is analyzed into its factors. R. B. S.

INORGANIC CHEMISTRY.—*The place of manganese in the periodic system.* F. RUSSELL V. BICHOWSKY. Journ. Amer. Chem. Soc. **40**: 1040–1046. July, 1918.

The older arguments placing manganese in the seventh group of the periodic system (*i. e.*, giving manganese a normal valence of 7) now appear open to question. On the other hand there are 12 different lines of argument based on purely chemical relationships which indicate its position in the eighth group. This conclusion is also in accord with the more decisive reasoning based on atom color presented in a previous paper. An improved form of the periodic table, showing the relations of the eighth and rare earth groups to the rest of the periodic system, is presented. F. R. B.

INORGANIC CHEMISTRY.—*The melting points of cristobalite and tridymite.* J. B. FERGUSON and H. E. MERWIN. Amer. Journ. Sci. **46**: 417–426. August, 1918.

The melting point of cristobalite has been redetermined and found to be 1710 ± 10° C. This value is consistent with the experimental evidence which was obtained in a study of a portion of the ternary

system CaO–MgO–SiO_2 and which had caused the earlier investigations to be viewed with suspicion. Tridymite is unstable at its melting point and this unstable melting occurs at 1670 ± 10°. Artificial tridymite made from quartz could not be melted owing to the rapidity of the tridymite-cristobalite inversion, but a sharp melting was obtained with natural material. Since this unstable melting point is below that of cristobalite, there can no longer be room to doubt that cristobalite is the high temperature form of silica. R. B. SOSMAN.

GEOLOGY.—*Asphalt deposits and oil conditions in southwestern Arkansas.* HUGH D. MISER and A. H. PURDUE. U. S. Geol. Survey Bull. 691-J. Pp. 271–292, with maps. 1918.

There are seven asphalt deposits in Pike and Sevier counties, Arkansas. The asphalt occurs in the Trinity formation of Lowe, Cretaceous age which rests on upturned edges of Carboniferous limestone and sandstone. Doubtless the asphalt is a residue of crude petroleum whose lighter and more volatile parts have escaped by evaporation. This petroleum is believed to have been derived from the Carboniferous rocks underlying the Trinity formation, near the base of which the asphalt is found. The geologic structure is not favorable to accumulation of petroleum, and the few wells that have been sunk for oil have not found it in commercial quantity. R. W. STONE.

GEOLOGY.—*Italian leucitic lavas as a source of potash.* HENRY S. WASHINGTON. Met. and Chem. Eng. **18**: 65–71. January 15, 1918.

This paper attempts an evaluation of the total amount of potash that is present in the lavas of the six chief Italian volcanoes along the west coast that have erupted leucitic lavas, which are therefore high in potash.

It is considered that in these volcanoes Italy possesses one of the largest if not the largest of the visible supplies of potash known to exist. Some other silicate rock sources of potash are briefly discussed, especially the Leucite Hills in Wyoming and the belt of glauconite that extends from New Jersey into Virginia. R. B. S.

MINERALOGY.—*Augite from Stromboli.* S. KOZU and H. S. WASHINGTON. Amer. Journ. Sci. **45**: 463–469. June, 1918.

This paper records the optical characters and chemical composition of the augite crystals that were being thrown out of the volcano of

Stromboli during the visit of A. L. Day and the authors in August 1914. Analyses of the lavas are also given. The augite is shown to be of a commonly occurring type. The paper is part of an investigation on the augites and other pyroxenes of Italian and other localities.

H. S. W.

VOLCANOLOGY.—*The representation of a volcano on an Italian renaissance medal.* H. S. WASHINGTON. Art and Archaeology **7**: 256–263. July–August, 1918.

This paper describes a lead medal of Leonello Pio, Count of Carpi, which dates from the beginning of the sixteenth century. The reverse represents a volcano in violent eruption, and it is shown that this commemorates almost certainly an eruption of Vesuvius in 1500, concerning the actuality of which there has existed considerable doubt. If so, this is the earliest known representation of Vesuvius in eruption.

H. S. W.

ENTOMOLOGY.—*Comparative morphology of the order Strepsipteras together with records and descriptions of insects.* W. DWIGHT PIERCE. Proc. U. S. Nat. Mus. **54**: 391–501, pls. 64–78. 1918.

This article comprises the second suppiement to a monographic revision of the order *Strepsiptera* published as Bulletin 66 of the United States National Museum. It contains additional biological studies on the occurrence of parasitism by these insects, and a review of all literature on the order which has been published since the first supplement. The leading feature of the article is the study of the comparative morphology of the order, tracing the modification of the various portions of the thoracic structures especially throughout the group. It is shown that the prescutum of the metathorax from being a transverse separate piece moves backward into the scutal area in the form of a triangular piece, and in successive modification tends to supply the scutum and approach, and even push backward the scutellum. It is shown that the changes in the thoracic structure can be coordinated with the antennal and wing structures which have previously been used for separating the families and genera. A more complete argument as to the reasons for separating the group as an order is presented together with a set of five rules for the formation of an insect order. A number of new species and genera are described and illustrated, and

the article also contains a large list of new host records and a bibliography of recent works. W. P. D.

ENTOMOLOGY.—*Medical entomology a vital factor in the prosecution of the War.* W. DWIGHT PIERCE. Proc. Ent. Soc. Wash. **20:** No. 5. Pp. 91–104. October 3, 1918.

The author brings out in this article the importance of entomological work in the study of diseases showing that the entomologist, parasitologist, and physician are all needed to work out their particular phases of the problems of disease transmission. Seven types of relationships of insects, disease organisms, and vertebrate hosts are defined. Various types of transmission of disease organisms by insects are also illustrated. The author brings out especially the importance of insect-transmitted diseases to armies and finally mentions a number of problems which still remain to be solved. W. D. P.

ANTHROPOLOGY.—*Kutenai tales.* FRANZ BOAS, together with texts collected by ALEXANDER FRANCIS CHAMBERLAIN. Bur. Amer. Ethnol. Bull. 59. Pp. 387.

This comprises 77 texts in the Kutenai Indian language with English translations, 25 with both interlinear and free translations. Forty-four were collected in 1891 by the late Prof. Alexander F. Chamberlain of Clark University, the remainder by Professor Boas in 1914. They are followed by 32 pages of Abstracts and Comparative Notes and Kutenai-English and English-Kutenai vocabularies. Kutenai constitutes one of the smaller linguistic stocks, Kitunahan, and embraces but two closely related dialects. The material is therefore of unusual value to the student of American languages, while the comparative notes render it equally important to the folklorist and those interested in comparative mythology. J. R. SWANTON.

APPARATUS.—*Calorimetric methods and devices.* WALTER P. WHITE. Journ. Amer. Chem. Soc. **40:** 1887–1900. December, 1918.

In this paper various forms of jacket covers (and of stirrer mountings) are described and compared. R. B. S.

APPARATUS.—*Some points regarding calorimeter efficiency.* WALTER P. WHITE. Journ. Franklin Inst. **186:** 279–287. September, 1918.

This discussion has special reference to the precision required and the conditions prevalent in commercial work. R. B. S.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

WASHINGTON ACADEMY OF SCIENCES

The Board of Managers met on January 27, 1919. A budget for the year was adopted, renewing the appropriations for 1918 with minor changes. A revision of the Standing Rules of the Board, as recommended by the Executive Committee, was adopted. The following appointments were announced: Members of Executive Committee, PAUL BARTSCH and WALTER T. SWINGLE; Committee on Membership: T. WAYLAND VAUGHAN, chairman, G. N. COLLINS, WALTER HOUGH, H. E. MERWIN, and E. T. WHERRY; Committee on Meetings: E. W. SHAW, chairman, C. W. KANOLT, H. H. KIMBALL, H. L. SHANTZ, and S. S. VOORHEES; Editor of Journal for term 1919–1921, ROBERT B. SOSMAN.

The following persons have become members of the ACADEMY since the last issue of the JOURNAL:

Mr. EDWARD CHESTER BARNARD, International (Canadian) Boundary Commissions, 719 Fifteenth Street, Washington, D. C.

Dr. SAMUEL JACKSON BARNETT, Department of Research in Terrestrial Magnetism, Carnegie Institution of Washington, Washington, D. C.

ROBERT B. SOSMAN, *Corresponding Secretary.*

GEOLOGICAL SOCIETY OF WASHINGTON

The 327th meeting of the Society was held in the lecture room of the Cosmos Club on April 10, 1918. The regular program was as follows:

EDWIN KIRK: *Paleozoic glaciation in southeastern Alaska.* During the past field-season a tillite of Silurian age was found in southeastern Alaska. Kosciusko and Heceta Islands, where the best Silurian glacial deposits are to be found, lie between 55° and 60° north latitude and 133° and 134° west longitude. These islands are situated on the west coast of Prince of Wales Island, toward the northern end. The most favorable locality for an examination of the conglomerate is in the large bay about midway on the north shore of Heceta Island. The coast here is well protected from storms and there is a continuous outcrop of the limestone underlying the conglomerate, the conglomerate itself, and the overlying limestone. In places the conglomerate is well broken down by weathering, making the collection of pebbles and boulders an easy matter. As exposed, the beds outcrop along the shore between tide levels, and give an outcrop perhaps 2,000 to 3,000 feet in length.

The glacial conglomerate is under- and overlain by fossiliferous marine limestones. The succession of beds is clearly shown and unmistakable. The strata as a whole in this region are badly disturbed, and as is the case throughout southeastern Alaska, contacts are very poorly shown, being, as a rule, indicated by an indentation of the shoreline and a depression running back into the timber. At present, therefore, although the relative positions of stratigraphic units are obvious, the character of the unconformity and the nature of the passage beds are poorly known.

The limestone series overlying the conglomerate carries a rich *Conchidium* fauna. In certain thin beds the rock is almost wholly made up of the brachiopods. This fauna appears to be identical with that of the Meade Point limestone of the Wrights and Kindle. The type exposure of the latter is at the northern end of Kuiu Island. At the base of the limestone at this locality is a boulder bed which I believe to be glacial in origin and to be correlated with the conglomerate of Heceta. The limestones below the conglomerate likewise carry a rich fauna consisting of pentameroids, corals, and gasteropods. The general aspect of both faunas seems to place them as approximately late Niagaran in age.

The conglomerate itself has a thickness of between 1,000 and 1,500 feet. In the main the conglomerate appears to consist of heterogeneous, unstratified, or poorly stratified material. Rarely lenticular bands of cross-bedded sandstone occur in the mass. These are clearly water laid and indicate current action.

The boulders in the tillite range in size up to two or three feet in length, as seen. The boulders consist of greenstone, graywacke, limestone, and various types of igneous rocks. Limestone boulders are scarce. All the boulders are smoothed and rounded. Facetted boulders are numerous and, given the proper type of rock, characteristic glacial scratches are to be found. The scratches show best on the fine-grained, dense greenstone. Limestone boulders and certain types of igneous rocks do not show them at all. The shoreline is strewn with these pebbles and boulders, which were undoubtedly derived from the conglomerate, as they are not to be found on the adjacent limestone shores. All the material collected was taken from the conglomerate itself, however. This is well broken down by weathering in some places, and the pebbles may be picked out with the fingers or tapped out with the hammer.

Throughout the Paleozoic section of southeastern Alaska are vast thicknesses of volcanic material, tuffs, breccias, and flows. Considering the sediments as a whole, climatic conditions through the Paleozoic do not seem to have been very different from those of comparatively recent times and physical conditions may have been very nearly the same.

H. E. Merwin and E. Posnjak: *The iron-hydroxide minerals.* Studies of composition, density, optical properties, and thermal be-

havior have led to the conclusion that only one compound of ferric oxide and water is known, $Fe_2O_3.H_2O$, which exists in two pure crystalline forms, goethite and lepidocrocite. The fibrous material commonly known as limonite is really fibrous goethite with additional water, silica, etc., held in capillaries. It has been possible to find a series of specimens representing the expectable properties of such impure fibrous goethite with variable water content. Turgite appears to be mix-crystals of $Fe_2O_3.H_2O$ and hematite, with properties varying according to the composition.

The amorphous brown iron ores when air dried contain sub-microscopic pores from which water has escaped, but they still hold in these pores variable amounts of water in excess of the formula $Fe_2O_3.H_2O$. They often show marked double refraction due to strain, but are readily distinguished from fibrous goethite by lack of splintery fracture and by lower refractive index.

All these minerals except well-crystallized goethite often occur in very close association.

J. B. MERTIE, JR.: *Repeated stream piracy in the Tolovana and Hess River Basins, Alaska.* The theme of particular interest to which this paper was devoted is an example of stream piracy effected by one stream at the expense of another; and a subsequent repetition of the same process under different physiographic conditions whereby the second stream recovered a considerable proportion of its former drainage. The present watershed therefore represents the third recognizable period of stability in the physiographic history of the two drainage basins.

The two streams in question are Livengood Creek, a tributary of Tolovana River, and the south fork of Hess River, in the Tolovana district, northwest of Fairbanks, Alaska. Gold-placer mining on Livengood Creek has furnished the necessary underground data on the configuration of bedrock under the gravels. An abnormally steep bedrock gradient at the lower end of the old bench channel on Livengood Creek justifies the inference that this stream in its earliest recognizable stage was much shorter than at present. The pronounced back-hand drainage of its present upper tributaries is regarded as corroboratory evidence of this hypothesis. Also the present divide between the two streams has been found by drilling to be silt-filled. An original stream piracy is thus deduced, whereby Livengood Creek stole the headwater tributaries of the south fork of Hess River. The depth to bedrock in the present silt-filled divide, and the depth to bedrock in a narrow gorge in the lower part of the south fork of Hess River, together with the elevations at these two localities, show exactly how much of the upper drainage of the south fork of Hess River was pirated.

The new physiographic condition that brought about the original piracy was a progressive drowning or inundation of the stream valleys

of the Yukon-Tanana region, which resulted in a regional elevation of the base level, and was accompanied by extensive silt alluviation. This new physiographic cycle took place in at least two stages, at the end of the first of which occurred a period of stability when the piracy of the south fork of Hess River by Livengood Creek was accomplished. Subsequently, these silt-filled valleys were drained, and the regional base level was reduced, and it was during this period that the final readjustment of the two drainage basins was effected, and the south fork of Hess River recovered a large part of its former drainage. Superposition of both streams onto bedrock has been responsible for the preservation of the present silt-filled watershed between them.

This topic is discussed in more detail in U. S. Geological Survey Bulletin 662-D, entitled "The Gold Placers of the Tolovana District, Alaska."

The 328th meeting of the Society was held in the Conference Room of the Director of the U. S. Geological Survey on May 8, 1918. The regular program was:

GEORGE OTIS SMITH: *A century of government geological surveys.* Published in A Century of Science in America. Yale University Press, 1918. Also in American Journal of Science Vol. 46, pp. 171–192, 1918.

At the 329th meeting of the Society, held on December 11, 1918, the Presidential address was delivered by the retiring President, FRANK H. KNOWLTON: *Evolution of Geologic climate.* The address will be published in full in the Bulletin of the Geological Society of America at a later date.

At the Twenty-Sixth Annual Meeting held on the same evening the following officers were elected for the ensuing year: *President,* E. O. ULRICH; *Vice-Presidents,* G. H. ASHLEY and H. S. GALE; *Treasurer,* WM. B. HEROY; *Secretaries,* R. W. STONE and R. S. BASSLER; *Members at-Large-of-the-Council,* L. W. STEPHENSON, H. G. FERGUSON, D. F. HEWETT, R. C. WELLS, EUGENE STEBINGER.

ESPER S. LARSEN, JR., *Secretary.*

WASHINGTON SOCIETY OF ENGINEERS

Ten meetings of the Society were held during the year 1918 as follows:

January 15, 1918: WILLIAM C. EDES, Chairman of the Alaskan Engineering Commission: *The Alaska Railroad.*

February 5, 1918: Joint meeting with the Washington Section of the American Institute of Electrical Engineers. Professor C. A. ADAMS, of Harvard University: *Standardization in engineering.*

February 19, 1918: Lieut. Col. HENRY S. GRAVES, Forester and Chief of the U. S. Forest Service: *The Forest Engineers in France.*

March 4, 1918: WILLIAM B. LANDRETH, Deputy State Engineer of New York: *Relation of the Barge Canal to the transportation problems of the United States.*

March 19, 1918: J. O. MARTIN, of the Chesapeake and Potomac Telephone Company: *Wires of war.*

April 1, 1918: Moving pictures of the Battle of Cambrai.

April 16, 1918: Hon. C. B. MILLER, Member of Congress from Minnesota: *Personal experiences on the Western Front.*

The regular meeting scheduled for October 8, 1918, was not held. This was in conformity with the wishes of the Board of Health, on account of the epidemic of influenza.

November 19, 1918: Moving pictures: *From ore to finished "National" pipe.*

December 3, 1918: Annual banquet. Speakers: EDWIN F. WENDT, President of the Society; ADOLPH C. MILLER, Member of the Federal Reserve Board; CHARLES PIEZ, Vice-President and General Manager of the Emergency Fleet Corporation; IRA W. MCCONNELL, of the American International Shipbuilding Corporation; Prof. O. M. W. SPRAGUE, of the Council of National Defense; and Dr. H. W. WILEY.

December 17, 1918: Annual Meeting for the election of officers; moving pictures illustrating the highways of the United States. The following officers were elected for the year 1919: *President,* MORRIS HACKER; *Vice-President,* WILLIAM C. THOM; *Secretary,* H. C. GRAVES; *Treasurer,* G. P. SPRINGER; *Members of the Board of Direction, 1919–1920,* JOHN C. HOYT, ANTHONY F. LUCAS, OSCAR C. MERRILL, EDWIN F. WENDT.

H. C. GRAVES, *Secretary.*

SCIENTIFIC NOTES AND NEWS

Dr. P. W. BRIDGMAN has returned from the naval experimental station at New London, Connecticut, to the Jefferson Physical Laboratory, Harvard University, Cambridge, Massachusetts.

Dr. EDGAR BUCKINGHAM, who has been associated with the work of the scientific attaché of the American Embassy in Rome, returned to Washington in February.

Dr. GEORGE H. A. CLOWES, formerly of the Gratwick Research Laboratory at Buffalo, N. Y., and lately engaged in research at the American University Experiment Station of the Chemical Warfare Service on the physiological effects of war gases, left Washington in January to take up biochemical research at the laboratories of Eli Lilly & Company, of Indianapolis, Indiana.

Dr. OLIVER L. FASSIG, of the U. S. Weather Bureau, has been elected secretary, and Mr. FRANCOIS E. MATTHES, of the U. S. Geological Survey, treasurer, of the Association of American Geographers.

Major General JOHN HEADLAM, who lectured before the Academy in April 1918, on "The development of artillery during the war," has been awarded the distinguished service medal by Secretary of War Baker, "for exceptionally meritorious and distinguished services rendered the United States Army while serving as chief of the British Artillery Mission to the United States."

Dr. ALES HRDLICKA, Curator of Physical Anthropology in the United States National Museum, has been made an Honorary Fellow of the Royal Anthropological Institute of Great Britain and Ireland.

Dr. M. S. SHERRILL, formerly with the Ordnance Department in Washington, sailed in January for an extended trip in South America.

Dr. F. H. SYMTH, formerly of the Massachusetts Institute of Technology, and lately captain in the Chemical Warfare Service, stationed at the American University Experiment Station, has received a temporary appointment as physical chemist at the Geophysical Laboratory, Carnegie Institution of Washington.

VILHJALMUR STEFANSSON was awarded the Hubbard Gold Medal of the National Geographic Society on January 10, 1919.

Word has been received that Mr. M. N. STRAUGHN, formerly of the Bureau of Chemistry in Washington, and a member of the Chemical Society, died in Porto Rico on January 9, 1919.